Sports Injuries

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2018

document version
Publisher's PDF, also known as Version of record

CHAPTER 8

GENERAL DISCUSSION

Sports are considered an investment in the present and in the future since they provide a powerful and high-impact avenue for the promotion and maintenance of sufficient levels of physical activity worldwide as well as for humanitarian, population-development, and peace-building purposes.[1–3] The paradox is that partaking in sports also brings a risk of injuries.[4] Injuries hamper sports participation and lead to negative consequences for the health and athletic performance of injured individuals and their sporting team.[5–7]

Given the negative impact of sports injuries on sports participation and athletic success, prevention is of great importance.[8,9] The main objective of this thesis was to facilitate, from a practical perspective, the prevention of sports injuries. This chapter discusses the main findings of the studies presented in chapters 2–7 and their implications. In addition, this chapter comprises a general discussion of the methods applied in the respective studies, as well as practical recommendations for future efforts regarding the prevention of sports injuries.

MONITORING SPORTS INJURIES

The research perspective – methods and outcomes are context-dependent

As mentioned in the **chapter 1** of this thesis, the prevention of sports injuries is not a standalone feature. There are specific steps to be taken for effective prevention, and such steps form a sequence (Figure 1, chapter 1).[10] The first step of this sequence is to establish the magnitude of the injury problem. The injury problem can be quantified when considering the occurrence (e.g. incidence, prevalence) and severity of injuries. Those descriptors are then considered the main outcomes when it comes to monitoring sports injuries and assessing the effectiveness of preventative strategies. Notwithstanding, there are multiple ways to quantify the magnitude of the injury problem in a population of interest, as described in **chapter 2**. There is no 'one-size-fits-all' approach to define what is considered a recordable injury within a study or injury-monitoring system,[11] or how the severity of injuries should be measured.[12] Consequently, there is no 'one-size-fits-all' monitoring system for sports injuries.[13]

In terms of injury occurrence, potential outcome measures can be prevalence (Equation 1, chapter 2) measured repeatedly over time or incidence density (Equation 4, chapter 2), for example. The first is preferred for overuse injuries (i.e. injuries with no clear identifiable onset)[14] and the latter is best applied for acute injuries only (i.e. injuries with a clear identifiable onset). Similarly, the severity of sports injuries can be quantified in different ways, such as by the amount of sport or working time-loss, or by the (in)direct monetary costs related to the handling of the injuries until full recovery. There is a considerable amount of effort been brought to standardise the methodology of injury surveillance in several sports,[15–22] which will definitely facilitate our understanding of the injury problem as well as comparisons among different studies and sports. However, there are no strict principles that should always be followed to ensure success in monitoring sports injuries. For this reason, it is important that stakeholders consider research findings and their context before designing and implementing an injury-monitoring system.

The end-user perspective – 'what's in it for me?'

Understanding the perspective of end-users (e.g. athletes and their staff) towards an injury-monitoring system is important since they are the ones who should use such a system in real-life situations. **Chapter 3** describes the acceptability and perceptions of end-users (i.e. elite judo, swimming, volleyball athletes, and their respective team staff) towards an online sport-health monitoring system. This online system was built based on the concepts described in chapter 2 and enabled athletes to register their exposure to sport as well as any health complaints over time. Also, this system generated reports to athletes' authorised staff on a regular basis, based on the registered information from athletes (Figure 2A, chapter 3).

Chapter 3 shows that the mean of the athletes' response rate to the online follow-ups was 50% (standard deviation [SD] 23), 61% (SD 27), and 56% (SD 25) for judo, swimming, and volleyball, respectively. This response rates were relatively low when compared with previous studies using a comparable strategy to record sports

injuries.[23,24] This difference in findings might be explained by the application of this online system as a practical tool (i.e. not as a research instrument), conducted without external control or influence from researchers on the use of the system by the end-users. Interestingly, athletes stated during the semi-structured interviews that they had expected to receive feedback on their responses to the questionnaires. This feedback would have motivated them to keep responding to the online follow-ups.

Apart from the lack of feedback, most athletes were satisfied with the system because they could register their exposure to sport and potential health complaints with a few clicks and did not need to type much. Staff members were also satisfied with the online system. The reports from the system facilitated the communication between athletes' respective trainer and medical staff. Since staff members were able to monitor their athletes' health, they could intervene earlier to prevent minor health complaints from becoming severe health problems.

The extent of the injury problem

Chapter 3 shows that the mean prevalence of injury measured repeatedly over a season of elite judo, swimming, and volleyball athletes was 26% (95% confidence interval [95% CI] 0–59), 19% (95% CI 0–65) and 36% (0–77), respectively. Similarly, **chapter 4** shows that the mean prevalence over a season of elite field hockey was 29% (95% CI 3–55). These findings are consistent with previous studies using the same methods to register injuries in different sports.[23,25,26]

Chapter 4 presents an assessment of the severity of injuries in elite field hockey using different measures in order to describe the overall burden of injuries on athletes' health, sport participation, and performance. Thirty percent of the injuries experienced by field hockey players were severe enough to hamper their training/competition participation and/or performance. Such injuries affected 52% of the injured players. This finding reinforces that, by hampering sports participation and performance, injuries may negatively affect team success over the season.[5–7] Moreover, chapter 4 shows that 50% of the injuries reported by players did not lead to time-loss from play.

Although the definition of injury is context-dependent, this finding confirms that defining an injury as one that leads to time-loss only will underestimate the magnitude of the injury problem in sports.[11] The same applies for defining injuries based on received medical attention, since 22% of the injuries described in chapter 4 did not receive medical attention.

THE PREVENTATIVE STRATEGY – MERELY MONITORING IS NOT ENOUGH

To commence injury prevention efforts in field hockey, in addition to chapter 4, **chapter 5** aimed to systematically review the literature on field hockey injuries in order to establish their extent in terms of rate and severity. It was possible to identify common injury characteristics in field hockey, such as the most injured body location (i.e. lower limb) and common types of injury (i.e. contusions/hematomas and abrasions). Contact injuries are common, but non-contact injuries are also a cause for concern in field hockey.

Such common injury characteristics may contribute to address injury prevention efforts. However, considerable heterogeneity among definitions and methods employed in the different studies prevented conclusive findings on the extent of the injury problem. Therefore, injury prevention efforts in field hockey will benefit from a consensus on the methodology of injury surveillance, such as consensus achieved in other sports.[15–22]

Despite the long history of field hockey and its popularity worldwide,[27] prospective studies focusing on overall risk of injuries are still sparse in this sport. As shown in chapter 5, the majority of prospective studies have investigated field hockey injuries together with injuries in other sports.[28–43] Within such studies, injury rates in field hockey were comparable with other team sports, such as basketball,[29,34,39] netball,[29,34] lacrosse,[39], and softball.[37,42] When comparing with football (soccer), the injury rate in field hockey can be considered low.[32,37,39,42] However, in major tournaments, the rate of time-loss injuries in field hockey[44] can be considered higher than football (soccer).[6]

These findings confirm that the risk of injury in field hockey should not be underestimated.

Although it was not yet possible to put a number on the magnitude of the injury problem in field hockey, chapter 4 and chapter 5 showed that this sport does entail a risk of injury. In an attempt to reduce the risk of injury in field hockey, the Royal Dutch Hockey Association (KNHB) have partnered with the Dutch Consumer Safety Institute (VeligheidNL). Together with field hockey and injury prevention experts, they have developed a structured exercise-based injury prevention program; i.e. the Warming-up Hockey program.[45] As part of this PhD-trajectory, we were asked to evaluate the effectiveness of this program in a quasi-experiment.

Chapter 6 shows that the exposure to the program was associated with a 36% lower injury rate (hazard ratio [HR] = 0.64 [95% CI 0.38–1.07]). The rate of lower limb injuries – the most common injured body location in field hockey, as shown in chapter 5 – was 46% lower (HR = 0.54 [0.29–1.02]) in the group following the Warming-up Hockey program. Similar findings have been reported by studies investigating the effect of exercise-based injury prevention programs on diverse youth team sports, such as football (soccer) and basketball, as well as in a meta-analysis.[46] Although not statistically significant in chapter 6, these results can be considered meaningful for practitioners given the significant 45% reduction of acute injuries (HR = 0.55 [95% CI 0.31–0.96]) and 48% reduction of injuries leading to 1–3 days of play time-loss (HR = 0.52 [95% CI 0.27–0.98]). In addition, the group following the program had a significant reduction of 8.42 (95% CI 4.37–12.47) days of play time-loss per 1,000 player-hours field hockey. For lower limb injuries, this difference was of 4.68 (95% CI 1.33–8.02) days of play time-loss per 1,000 player-hours.

The adherence to the Warming-up Hockey program by coaches and players during the study period was high. The median of the weekly adherence to the intervention program by coaches was 93% (25%–75% interquartile range [IQR] 74–100). The median of the actual intervention 'uptake' by players was 84% (IQR 59–88). However, an important limitation to the intervention adherence was the indoor season period

(Figure 2, chapter 6). The indoor season is an official period in the Netherlands due to the weather conditions during winter. Training and games logistics change substantially during the indoor season period. Further investigation is needed to verify the feasibility of potential adaptations to the warm-up program or in the logistics of the indoor season to facilitate the adherence to the program during this indoor period. The effect of such a higher adherence to the warm-up program during the indoor season on injury outcomes (e.g. rate, severity, and burden of injuries) should also be investigated.

METHODOLOGICAL CONSIDERATIONS

Each study within this thesis was carried out with great care. Notwithstanding, all had methodological strengths and limitations, which have been discussed more specifically in their respective chapters. In addition, this section highlights some considerations to be taken when interpreting the overall results described above.

Convenience sampling

The studies in chapter 3, 4, and 6 did not have the luxury of including a random sample of participants. This means that the participants of these studies were selected by convenience, according to what was feasible within each respective study. A sample selected by convenience may, by default, not represent the entire (sporting) population well. The inclusion of participants as well as their characteristics are described in detail in the respective chapters. This description is meant to contribute to the interpretation of the context and specific population in which each study was conducted. Stakeholders should, therefore, consider the contexts in which these studies were conducted and interpret our results with caution before generalising them to other sporting settings.

The studies in chapter 3 and 4 were conducted in elite sporting settings. It is important to acknowledge that the samples of these studies were relatively small and selective. However, it is also important to acknowledge that these 'selected' athletes also require

appropriate healthcare and should be studied for this reason. What has happened over the years in the field of sports medicine is that non-elite-level (e.g. recreational) athletes have been studied and results of these groups have been generalised to inform prevention and care in elite sporting contexts. Such evidence, and the resulting practical implications, are then based on a mean outcome of groups of non-elite athletes. Elite athletes, however, usually do not fit the mean. They are most likely the upper limit in terms of physiology, strength, conditioning, etc. After all, they are elite athletes. From a public health perspective, localised, contextual approaches are needed for studying health outcomes, even within a relatively small and selected study population.[47] This same reasoning can be applied for the study in chapter 6, which consisted of youth, non-elite athletes selected by convenience.

Self-report data

Self-report is a widely used method to collect information on individual's health status and usage of healthcare services.[48] In sports, athletes' self-report has been used to measure athlete's health status, which enabled the description of the injury problem in a variety of contexts.[23–25] Participants' self-report was also the approach used to collect data for the studies in this thesis. In chapters 3 and 4, athletes registered their exposure to sport and health complaints over the sporting season. This registration was done online, which has a number of advantages, as described in chapters 2. An online approach was also used in chapter 6, where coaches registered the sport exposure of youth athletes and the reason of their absence in training/competition (e.g. injury). In case of injury, athletes' parents were asked to register the injury details online (e.g. onset, body location, mechanism). The prospective injury registration and classification in each study was conducted systematically using valid instruments, which can be considered a strength of the studies. Unfortunately, it was not possible to have a medical professional on the field to diagnose the injuries reported by the participants of the studies in this thesis due to logistic reasons.

Despite of the wide use in research, the accuracy and validity of self-report measures are still a matter of investigation.[48] This investigation is needed since self-report measures can potentially differ from objective measures. However, self-report measures are considered sufficiently accurate when requiring short recall periods (e.g. a month).[48] Therefore, the close follow-up (i.e. weekly and every other week) of participants conducted in the studies of this thesis can be considered of sufficient regularity to provide accurate information. On the other hand, identifying whether study participants report their actual (health) status still remains a challenge in sports medicine research.[49] Given the practical value of subjective measures, however, self-report measures are useful and sporting stakeholders are encouraged to use them on a regular basis.[50] Ideally, self-report data collection should be able to acquire quality and meaningful information from the athlete with the lowest burden possible.[51] This was the mind-set behind the studies of this thesis.

Mixed methods research

Mixed methods are useful to combine qualitative and quantitative study paradigms and converge findings in the context of complex research questions.[52] The answer of (complex) questions dominated by practice often requires more than one research paradigm (i.e. qualitative and quantitative). The study in chapter 3 was pursued in a mixed methods approach to investigate the acceptability and perceptions of end-users towards a health-monitoring system. The adherence of athletes to a regular registration of sport exposure and health complaints was assessed quantitatively. The perception of athletes and their team staff (i.e. end-users) towards the system was analysed qualitatively. Although specific details on the study methodology is described in chapter 3, it is important to further clarify how methods were integrated so the reader can self-assess the strengths and limitations of the study.

The integration has occurred at the study design, methods, and reporting levels.[53] At the study design level, integration was achieved by using an explanatory sequential design – the quantitative data collection started first, and qualitative data was collected

subsequently. This enabled end-users to experience the online system as well as the descriptive analysis of athletes' response rate (i.e. quantitative data) to the online follow-up over the season. Face-to-face interviews (i.e. qualitative data) were conducted subsequently, at one follow-up point of the study, to investigate the perceptions of end-users towards the system. At the methods level, integration was achieved through connecting – interviewees were sampled by convenience from the database of respondents to the online follow-ups. At the reporting level, integration was approached using a contiguous narrative – quantitative and qualitative findings were presented in different sections within the results section. Although with limited generalisability, chapter 3 does show that, in an elite sporting context, it is viable to register health complaints systematically and to act thereon to protect athletes' health. These results should lead to future studies and policies that aim to further develop this approach to protect the athletes' health and their ability to perform.

Quasi-experiments

As discussed in **chapter 7**, the effect of a preventative strategy is preferably evaluated in a randomised controlled trial because this is the most rigorous design to infer a cause-effect relationship.[54] When investigating the efficacy of an intervention (e.g. a preventative measure), one takes into account any potential confounding factors, and offers the intervention the best conditions to demonstrate its true effect. Such well-controlled study characterises an explanatory trial,[55] and answers the question 'does the intervention work under ideal conditions?'.[56] There are also trials conducted under a less-controlled setting, which investigate effectiveness rather than efficacy.[57] These are the so-called pragmatic trials, which answer the question 'does the intervention work in a real-world context?'.[56]

Chapter 6 comprises a quasi-experiment (i.e. a non-randomised controlled trial) conducted to assess the effectiveness of an exercise-based injury prevention program. The developers of the program under investigation had already released the program in its online platform when they requested for the study in chapter 6. Due to this

constraint, it was not possible to conduct a randomised controlled trial to investigate the effect of the intervention program. Participants were, therefore, allocated to the intervention or control group based on their personal preference. The non-random allocation of participants to intervention and control group limited the internal validity of the study.[58] Restricted internal validity means that it is not possible to draw generalizable conclusions on the cause-effect relationship between the intervention and observed injury outcomes. On the other hand, the quasi-experimental design of the study leads to a certain level of external validity regarding comparable populations and settings, which means that it can be considered closer to a real-world context in which the findings are to be applied.[59]

PRACTICAL RECOMMENDATIONS

Monitor the athletes, not only the injuries

Although each sport has its specific demands and levels of training and competition, injuries are a burden on athletes' health, sports participation and performance, regardless of the sport.[4,5] Continuously monitoring athletes' health will facilitate earlier detection of health complaints and earlier intervention, as shown in chapter 3. Earlier intervention can prevent minor health complaints from becoming severe and costly health problems. Athletes' health complaints can also be related to illnesses, which should also be considered in further preventative efforts in sports. Continuous health-monitoring may be, arguably, closer to the reality of elite sports than to the reality of amateur and recreational sports due to resources availability. However, elite sports will serve as an example and role model for sports and physical activities at the amateur and recreational level. Elite sports have proven to be a valuable asset to increase participation rates through positive exposure and outstanding results. Through the same principle, elite sports also inspire and influence others in game tactics, image building, branding, etc. Health monitoring, and injury and illness prevention could and should also be part of such carry-over effects. Accordingly, health monitoring and the prevention of injuries and illnesses at an elite level not only provide safety and

health for the athletes themselves, who are exposed to high loads, but also aid dissemination of the same messages to the wide-base of other participants enjoying their sport at amateur and recreational level.

Involve the end-user

Scientific evidence on effective prevention of sports injuries generally do not reach the intended end-users (e.g. athletes, coach, physiotherapist).[60–62] This might be due to the available information being e.g. too specific for the research setting in which it has been evaluated; uninterpretable for the end-user; and/or scattered over various publications, etc. Therefore, a practical scheme that is able to bridge the gap between research and practice is required. Critical parts of that bridge are: local feasibility of the intervention; knowledge that must be presented in a meaningful way for the end-user; and also, the motivation of the end-user to support the need for implementation.[60,63,64] Therefore, involving the end-user in multiple ways is the key to bring evidence on effectiveness and implementation truly into the sporting field.

Verhagen et al.[65] have proposed a knowledge transfer scheme (KTS) that integrates existing research frameworks into a tool for practical solutions (Table 1). Basically, by following the KTS, sporting stakeholders will (1) describe the problem; (2) synthesise and describe the evidence available that supports the problem-solving; (3) establish a multidisciplinary group, including end-users; (4) develop a potential problem-solving product; and (5) evaluate the translatability and feasibility of the product in a real-world context. The first four steps of the KTS was used by KNHB and the Dutch Consumer Safety Institute (VeiligheidNL),[66] which subsequently resulted in the exercise-based injury program for field hockey evaluated in chapter 6. The KTS was also successfully applied by Hespanhol Junior et al.,[67] who, at the end of the KTS-process, showed that online tailored advice can prevent running-related injuries. Since the KTS provides a platform for multiple stakeholders to engage in the development of evidence-based solutions and their sustainable implementation,[65] the KTS should be considered for future efforts on sports injury prevention.

Table 1. Overview of the five steps of the Knowledge Transfer Scheme (KTS).[65]

Step 1 Problem statement	Describe the problem in terms of: ▸ problem magnitude ▸ problem severity ▸ societal burden ▸ problem context
Step 2 Evidence synthesis and description	For all available evidence, describe the: ▸ gain for the individual ▸ gain for the society ▸ context of the evidence ▸ contemporary views and practices of practice and practitioners
Step 3 Establish a knowledge transfer group (KTG) consisting of representativeness of key stakeholders, practitioners, and researchers with expertise on the injury or evidence at hand	Within the KTG, discuss the: ▸ problem statement (KTS step 1) ▸ evidence description (KTS step 2) ▸ completeness of group (e.g. in the event that the group identifies that some key stakeholders or experts are missing, they can be added to the KTG)
Step 4 Product development	For the KTS product to be developed, describe the: ▸ product goal ▸ target group(s) ▸ product context
Step 5 Evaluation	Evaluate the KTS product within the RE-AIM Framework:[68] ▸ reach ▸ effectiveness ▸ adoption ▸ implementation ▸ maintenance

Embrace online technology

The field of sports medicine can and should take advantage of the online resources currently available to facilitate injury prevention efforts. For athlete health monitoring, there is a number of advantages of using online data collection, as discussed in chapter 2. An example of an automated workflow for monitoring athletes' health is shown in the figure 2A of chapter 3. The workflow was automated using R,[69] which is an open source (free) programming language and software environment for statistical computing and graphics.[70] In such a workflow, online technology enables the automation of data collection, analysis, and reporting. All these steps then can be done more quickly and systematically, generating meaningful output for those in the decision-making process to protect athletes' health.

A theoretical example of how online technology can facilitate the protection of athletes' health is the systematic approach proposed by Verhagen and Bolling.[71] In such an example (Figure 1), online technology would collect relevant data from athletes and their team staff and provide them with meaningful feedback to support their practice. A central platform would then aggregate all the data for research, which would subsequently support the development and implementation of optimised strategies for prevention, management, and rehabilitation of athletes' health conditions. Although building such a system is theoretically possible, its development and implementation is yet to be done. There is a need for finding the proper set up for this approach with the lowest burden for the athlete and staff as possible. Naturally, this will also depend upon the type of sports and type of health conditions one may expect. Those interested in developing and implementing a monitoring system such as the one illustrated in Figure 1 should be aware of the current legislations on data protection and privacy applicable to their setting and obtain the appropriate informed consent from the end-users.

Online technology can also aid the delivery of preventative strategies, such as done in chapter 6. Several organisations have recognised the power of online technology to increase health and safety in sports worldwide. Such organisations have also released open source resources that can be reached by anyone with a phone and access to the

internet. The International Olympic Committee, for example, released an application to help athletes and their staff to prevent sports injuries. The 'Get set' application presents injury prevention exercises grouped by body location or sports to be carried out with minimum equipment.[72] Even relatively simple platforms can be used to disseminate the message of sports injury prevention. For example, the Brazilian Olympic Team has shared a YouTube playlist of injury prevention exercises.[73] YouTube is a widely used platform aiming to 'give everyone a voice and show them the world'.[74] Sporting stakeholders can use such a platform to reach end-users and disseminate the knowledge on sports injury prevention, as well as its importance for public health.

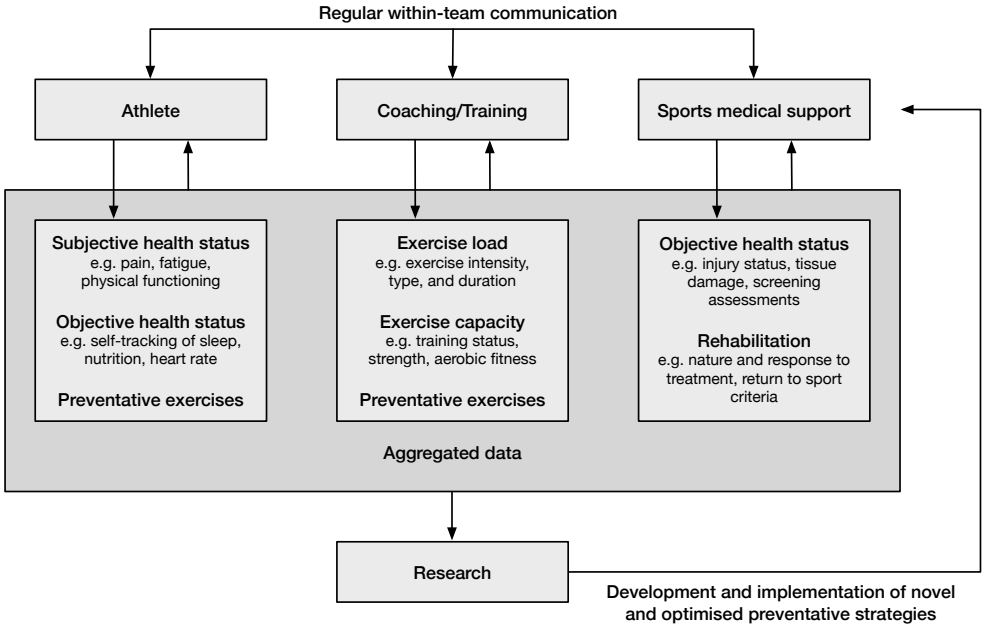

Figure 1. A theoretical approach to protect the health of the athlete using online technology adapted from Verhagen and Bolling.[71] End-users (i.e. athletes, coaches/trainers and medical staff) input data to a 'system'. The data from end-users is aggregated and made securely available for members, tailored to their respective authorised access, needs and wishes. The aggregated data result in research output and optimisation of athlete healthcare.

KEY POINTS

- Monitoring of athlete health is feasible with simple secured online technology and aids the effort for prevention of sports injuries. Sports-health monitoring systems can provide direct value for end-users' (i.e. athletes and team staff) practice and also research output.
- The value of health monitoring should be clearly presented to end-users (i.e. athletes and their staff), who, together with researchers, should be actively involved in the design and implementation of health monitoring systems. For sustainability, it is important to document the purposes of such monitoring systems and the roles and responsibilities of each stakeholder in it. The workflow of each stakeholder in the system should be clear, as well as what they will 'get out of it'.
- Heterogeneity exists in definitions and methods applied in studies measuring the extent of the injury problem in sports. Although such heterogeneity can hamper conclusive findings on the magnitude of the injury problem, it should not impede preventative efforts to protect athletes' health.
- Structured warm-up programs are valuable for the prevention of sports injuries and online technology can aid the delivery of such programs in a real-world context. Such a structured warm-up program delivered to coaches using online technology shows positive results for reducing injury rates and burden of injuries on youth players' participation in field hockey.

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